Region 1 EPLO Conference

20-22 October 2000, Fairlee, VT

Introduction to River Ice Jams and Mitigation

Ice Engineering Research Division

US Army Cold Regions Research and Engineering Laboratory

CRREL

Cold **Problem Solvers for the World**

Key difference: higher stages occur more rapidly and at lower discharges during ice jam events than open water events

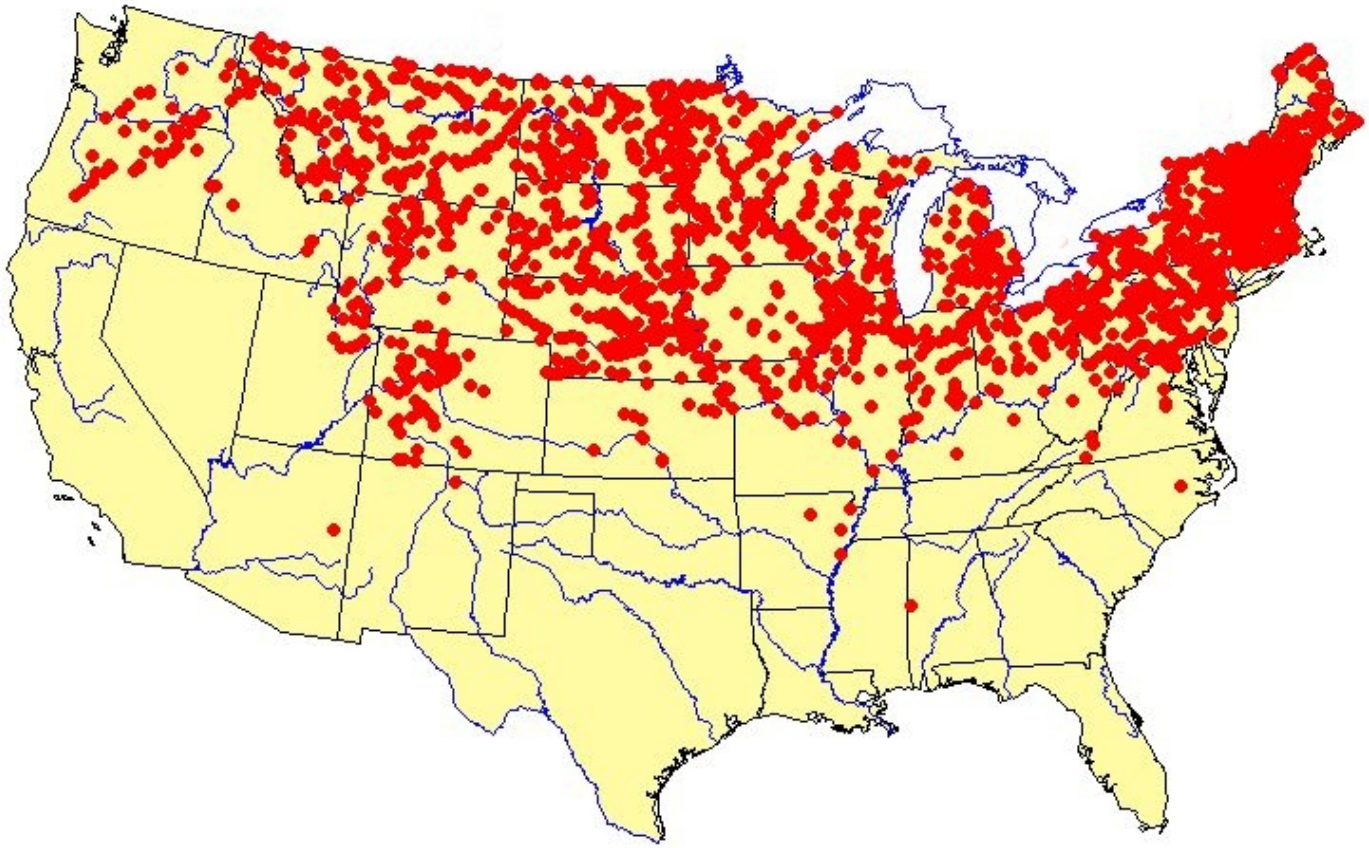
IAHR Working Group on River Ice Hydraulics Definition

An ice jam is a stationary accumulation of fragmented ice or frazil that restricts flow

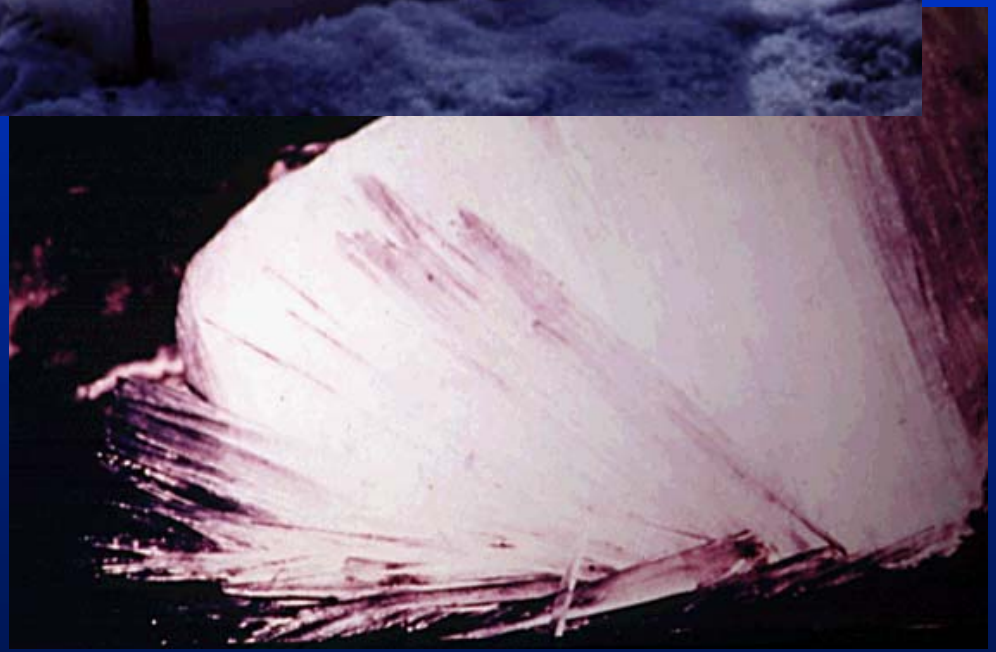
Ice Jam Formation

- Jams are possible wherever an ice cover forms
- Jams occur at locations where the river's transport capacity is exceeded
  - Intact ice cover
  - Sharp bends
  - Decreases in channel slope
  - Constrictions
  - Confluences
- Ice jam flooding can be extremely rapid
- Two types of jams: freezeup and breakup

Reported Ice Jams



CRREL Ice Jam Database



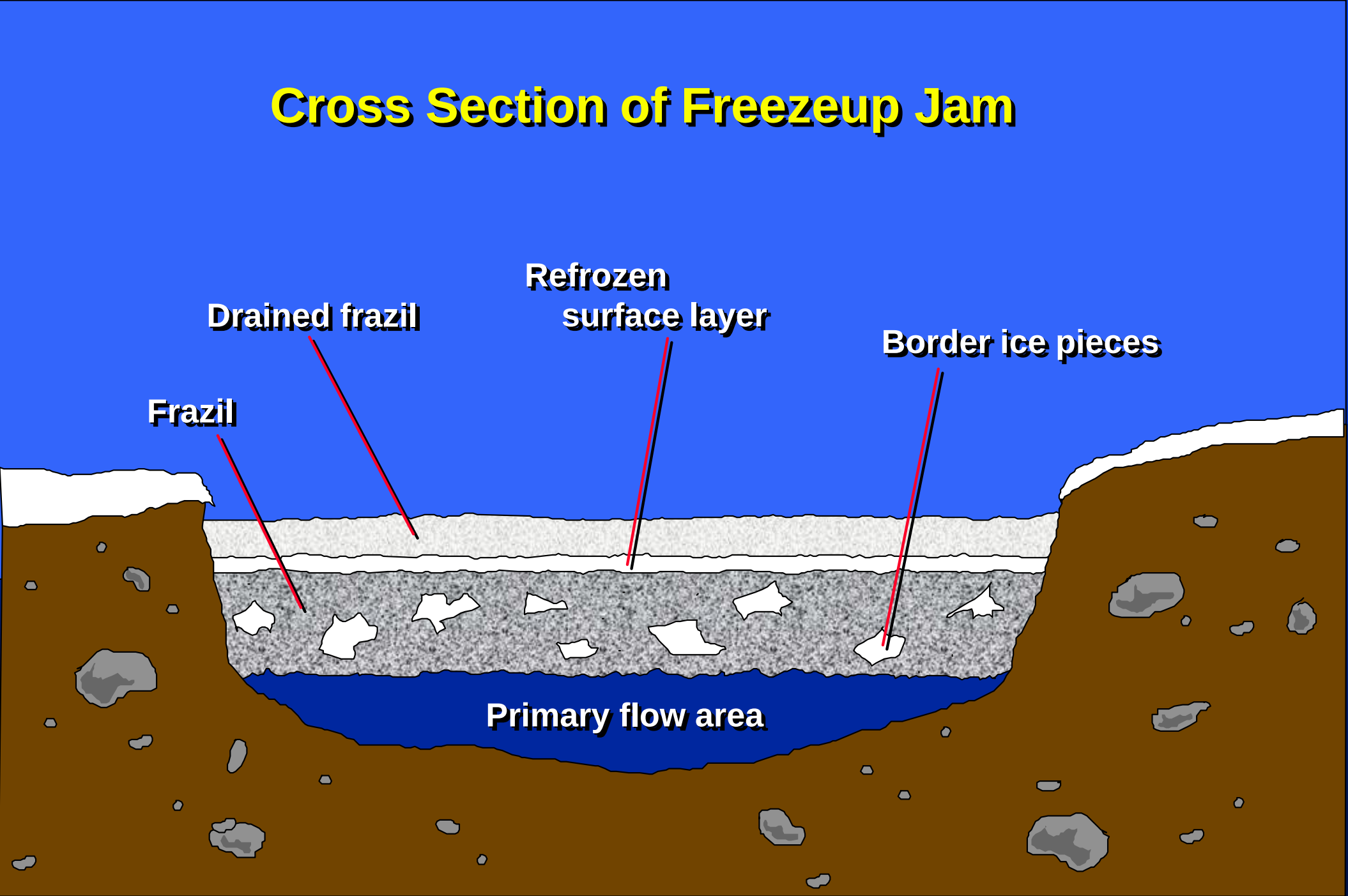
•**Columnar ice:** Thermally-grown “black” ice, transparent, allows solar penetration, decays into “candled ice”

- **Fine grained ice: made of frazil or snow, looks “white”, resists solar penetration**

Freezeup Jams

- Early to mid-winter formation
- Subfreezing air temperatures
- Frazil and broken border ice
- Unlikely to release
- Fairly steady water flow
- May exhibit cohesion
- Smooth to moderate surface roughness

Cross Section of Freezeup Jam



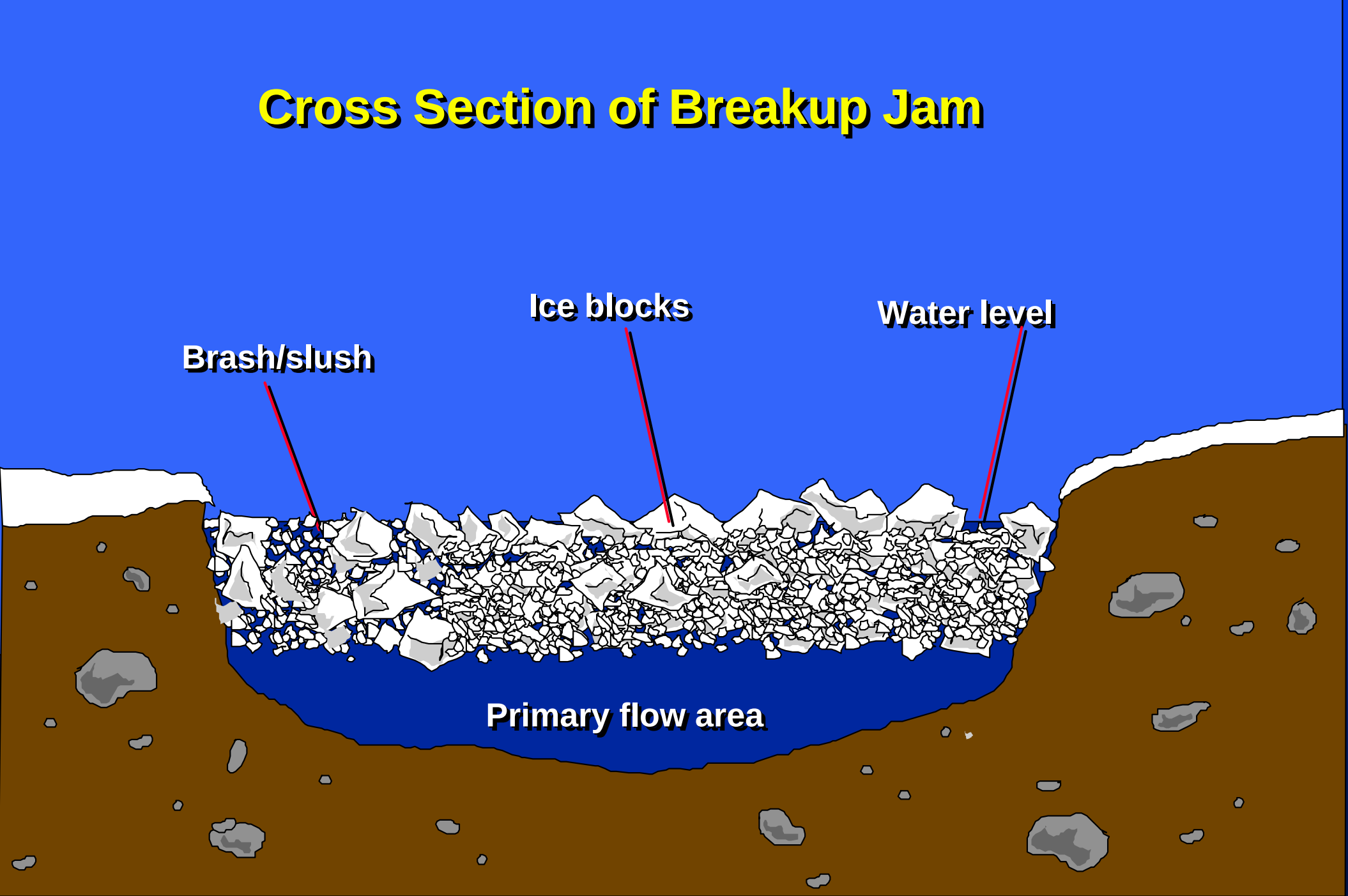
River Ice Cover Breakup

- Thermal Breakup: Ice cover melts in place
  - Direct sunlight plays a large role
  - Surface color influences absorption of sunlight: Dusting ice promotes melting
  - Water on ice decreases reflection, may promote melting
  - Open water areas absorb sunlight
- Mechanical Breakup: Hydrodynamic forces acting on cover exceed cover strength
  - Results from an increase in flow
  - Precipitation event
  - Snowmelt event
  - Dam operation

Breakup Jams

- Mid to late winter formation
- May form more than once per season
- Near-freezing air temperatures
- Broken sheet and border ice
- Highly unstable, releasing suddenly
- Unsteady water flow (surges)
- Moderate to extreme surface roughness
- Midwinter jams may refreeze, causing additional problems later in the winter

Cross Section of Breakup Jam



Ice Jam Mitigation

- **Advance Measures**
- **Emergency Measures**
- **Permanent Measures**
- **Freezeup Jam Control**
  - Control production and transport of frazil ice
  - Displace jam initiation location
- **Breakup Jam Control**
  - Control timing of ice breakup
  - Displace jam location

Mitigation Goals

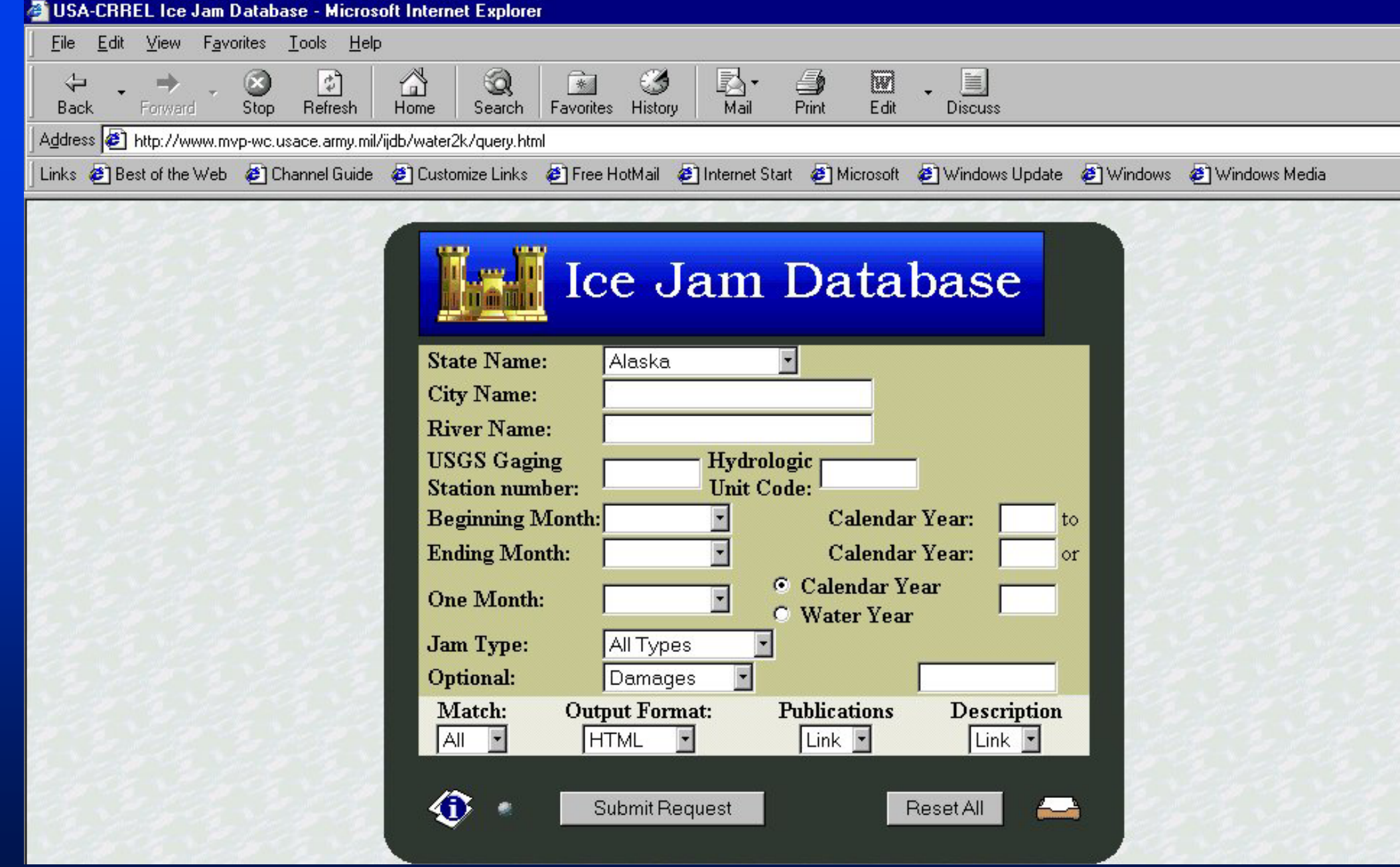
- Advance Measures
  - Flood protection
  - Reduce ice supply
  - Control breakup sequence
  - Increase conveyance
- Emergency Measures
  - Flood Protection
  - Increase Conveyance
  - Remove Ice
- Permanent Measures
  - Flood protection
  - Reduce ice supply
  - Increase conveyance
  - Control breakup sequence
  - Displace ice jam location

Advance Measures

- Non-structural intervention
- Two weeks to six months lead time
- Can be inexpensive
- Effective?
- Includes monitoring, early warning, ice weakening

Early Warning

- Provides critical information
- Two weeks to six months lead time
- Inexpensive and invaluable
  - Trained observers
    - Part of emergency response team
    - Track pre-event ice conditions and during event
    - Helpful for after-action assessment
  - Ice motion detectors
    - Trip wires in ice
      - alarms inform emergency managers
      - select locations to give days/hours warning
      - Can be remote



http://www.crrel.usace.army.mil/products/products.html

Address http://www.nws.noaa.gov/er/nerfc/ice Go Links

NERFC River Ice Information

In order to achieve the NERFC mission, we require close cooperation and interaction between a number of weather forecast offices. These offices include Buffalo NY, Binghamton NY , Albany NY, Brookhaven NY, Burlington VT , Taunton MA, Gray ME , and Caribou ME . Since river ice floods are very local in nature, people in ice jam prone areas should stay in touch with local officials during periods of impending danger.

The National Weather Service in cooperation with local officials periodically provides watches and warnings.

- Flood Watches and Warnings

To effectively combat the potentials of river ice problems, the NERFC is experimentally setting up a river ice monitoring network. This network is composed of concerned citizens, local emergency managers, and government officials, who periodically report on the characteristics and the development of river ice during the winter/early spring season. Below are links to some of their contributions.

Latest Ice Reports

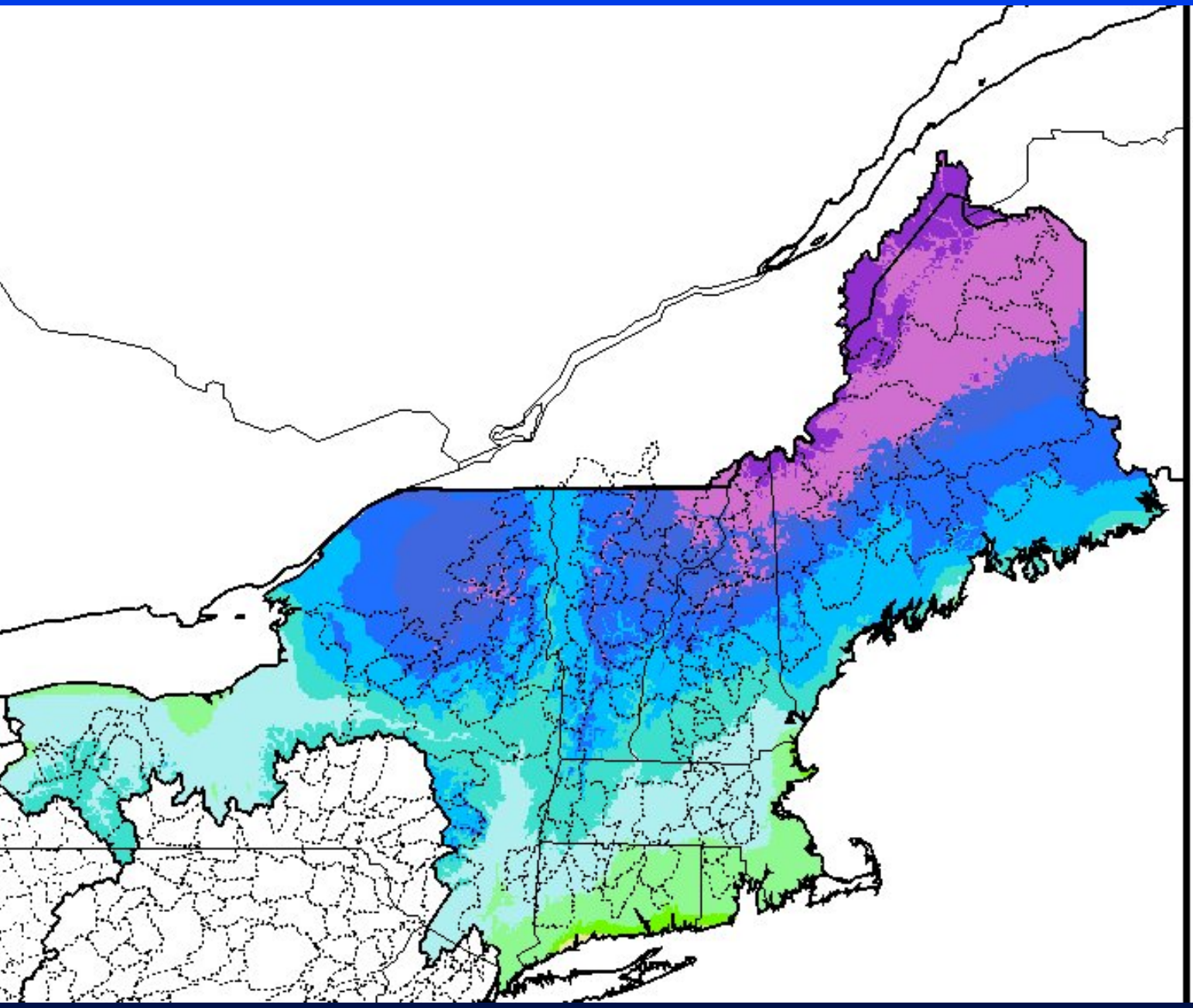
- Western New York
- Eastern New York
- Southern New England MA/CT/RI
- Vermont
- New Hampshire
- Maine

www.nws.noaa.gov/er/nerfc/ice

- SUBMIT A REPORT

Current Conditions

- Mean Daily Air Temperature Map from NOHRSC.
- Thawing Degree Days
- Freezing Degree Days



FREEZING DEGREE DAYS

Oct 1, 2000 to Mar 8, 2001

Northeast River Forecast Center

CUMULATIVE DEGREE DAYS (F.)

- 2026 to 2265
- 1788 to 2026
- 1550 to 1788
- 1311 to 1550
- 1073 to 1311
- 834 to 1073
- 596 to 834
- 357 to 596
- 238 to 357
- 119 to 238
- Not Estimated

National Operational Hydrologic Remote Sensing Center

IWDS Home Page - Microsoft Internet Explorer

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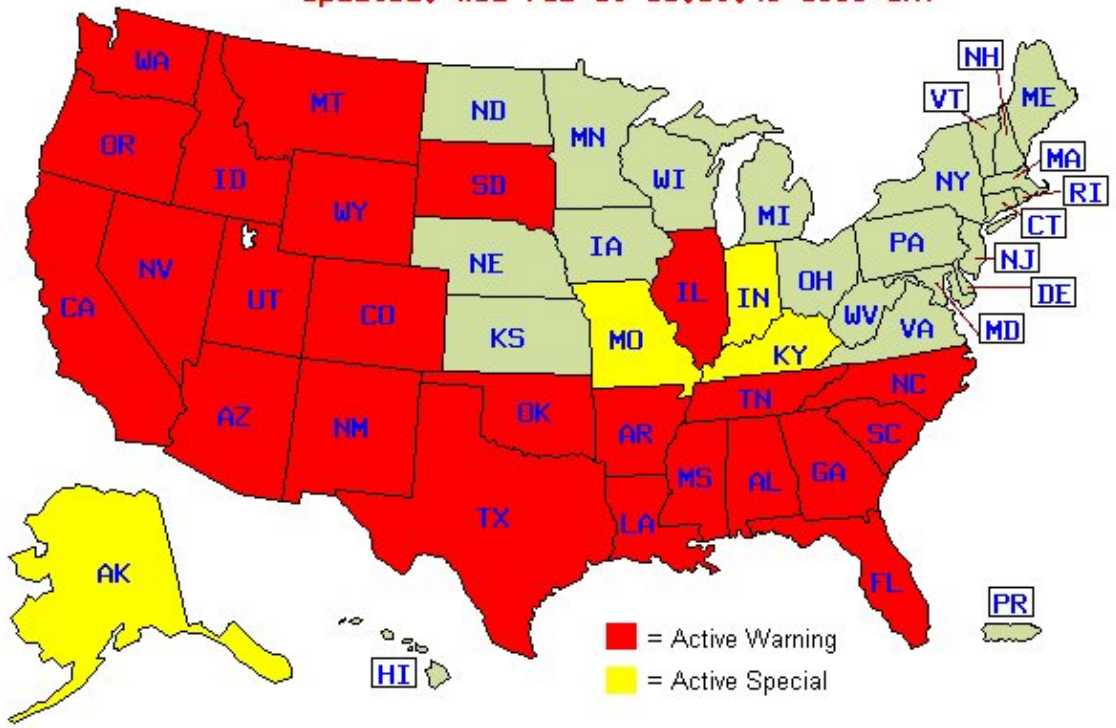
Address http://iwin.nws.noaa.gov/iwin/iwdspg1.html

Interactive Weather Information Network ----By the National Weather Service

NEW-- Major Storm? BUSY? SLOW? ALTERNATE LINKS ->Click here -> Live Weather and Warning data streams over Internet!-- FASTER DOWNLOADS of live Weather Warnings HERE!.

Updated: Wed Feb 10 16:50:49 1999 GMT



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Back to Main

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FLOOD STATEMENT
NATIONAL WEATHER SERVICE STATE COLLEGE PA
1100 AM EST THU FEB 17 2000

ICE JAM CONTINUES ON CLEARFIELD CREEK NEAR DIMELING. SCRIBNERS ROAD IS STILL CLOSED.

AT 1030 AM THIS MORNING...CLEARFIELD COUNTY EMERGENCY MANAGEMENT OFFICIALS REPORT SOME MINOR CHANGES TAKING PLACE. WATER ALONG THE CLEARFIELD CREEK IS STILL FLOWING ONTO SCRIBNERS ROAD. THE WATER IS ALSO PUSHING ICE ONTO THE ROAD. THE CHANGE IS IN THE CHARACTER OF ICE THAT IS JAMMING. THE ICE THAT IS JAMMING IS NOW LARGER SHEETS OF ICE THAT ARE STACKING VERTICALLY. THE HIGHER STACKS OF ICE IN THE JAM MAY BACK WATER TO EVEN HIGHER LEVELS DURING THE NEXT THAW. SO FAR THE WATER LEVEL BEHIND THE JAM REMAINS UNCHANGED FROM YESTERDAY. AND NO HOMES ARE BEING AFFECTED. THE ROAD IS COVERED WITH ICE AND WATER FOR A DISTANCE OF ONE TO TWO MILES...DOWNSTREAM OF THE DIMELING BRIDGE.

ANOTHER ICE JAM IS OCCURRING UPSTREAM ON CLEARFIELD CREEK...BETWEEN IRVONA AND COALPORT IN BECCARIA TOWNSHIP. THERE ARE AT LEAST 7 HOMES THREATENED BY THIS JAM BUT NO FLOODING IS OCCURRING AT THIS TIME.

FURTHER UPSTREAM...IN CAMBRIA COUNTY...YET ANOTHER ICE JAM ON CLEARFIELD CREEK IN WHITE TOWNSHIP...HAS BACKED ICE UP FOR 3 QUARTERS OF A MILE. THE ICE FROM THIS JAM IS BACKED UP AGAINST THE FOSTER ROAD BRIDGE...BUT NO FLOODING IS BEING REPORTED AT THIS TIME.

ADDITIONAL ICE JAMS ARE STILL POSSIBLE THIS AFTERNOON AND TONIGHT ALONG CLEARFIELD CREEK...WHICH COULD RESULT IN ADDITIONAL FLOODING. ICE JAMS CAUSE RAPID FLUCTUATIONS IN WATER LEVELS. IF YOU LIVE NEAR A RIVER OR STREAM...BE READY TO ACT QUICKLY IF ICE JAMS FORM OR A WARNING IS ISSUED.

DO NOT DRIVE YOUR VEHICLE INTO AREAS WHERE THE WATER COVERS THE ROADWAY. VEHICLES CAUGHT IN RISING WATER SHOULD BE ABANDONED.MOVE TO HIGHER GROUND.

.END/ HEAD

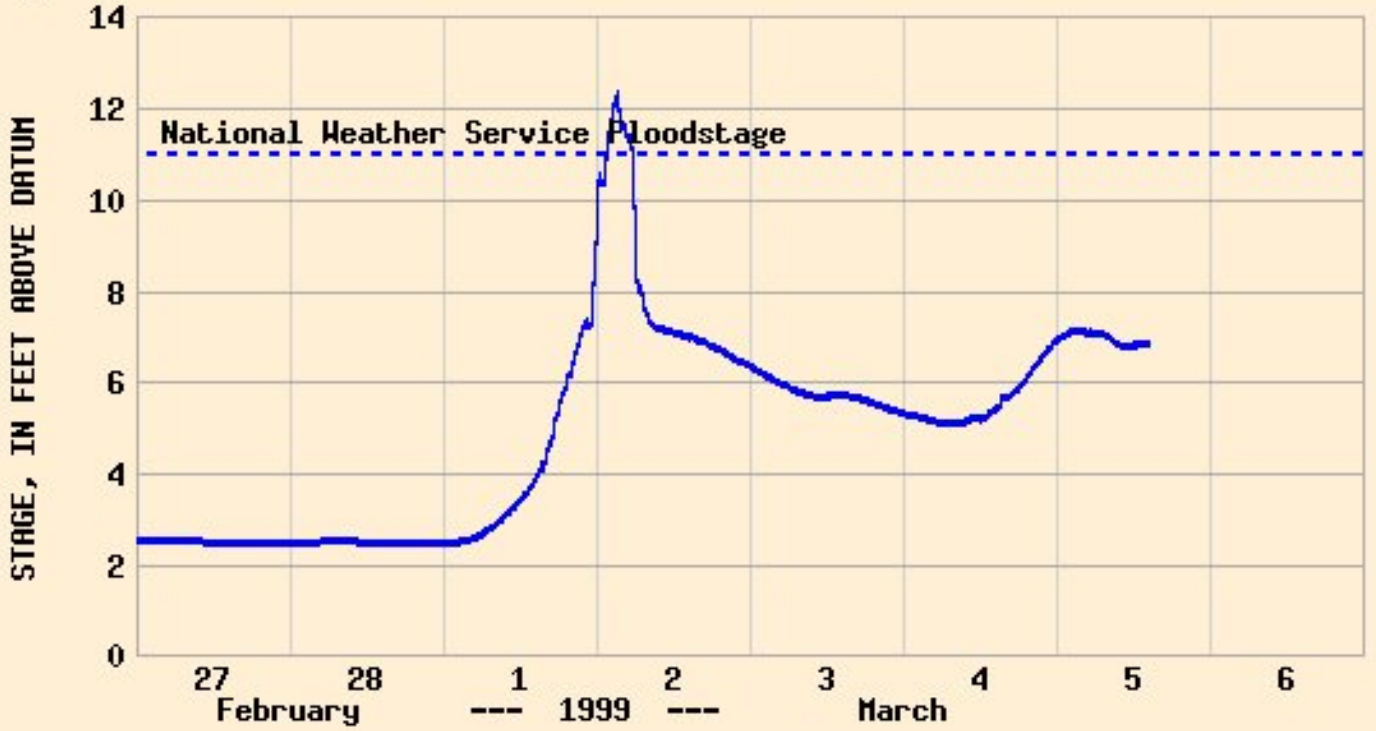
LAT...LON 4033 7895 4031 7872 4113 7817 4117 7873

New York Current Surface Water Conditions
Updated Wed Feb 10, 1999 11:27

PROVISIONAL DATA SUBJECT TO REVISION--Select a station number from the table or a site from the current conditions map to view graph(s) and other data for a station. Tables and graphs are updated hourly however actual data retrieval frequency varies by site (hourly, 4-hour, twice-daily, or daily).

Station Number	Station Name	Long-term median flow 02/10	Flow	Stage	Water Temp	Date/Time
	SITES ON LONG ISLAND					
01310521	Reynolds Chan'l At Pt Lookout	--	--	-0.6	38.7	02/10 10:45
	HUDSON RIVER BASIN					
01314500	Indian Lake nr Indian Lake	--	--	***	--	--- ---
01315500	Hudson River At North Creek	900	1230	3.7	--	02/10 08:45
01318500	Hudson River At Hadley	1580	2830	4.1	--	02/10 09:45
01321000	Sacandaga River Near Hope	487	Ice	2.7	--	02/10 09:30
01323500	Gr Sacandaga L at Conklnvl	--	--	752.5	--	02/10 09:45
01325000	Sacandaga R Stew Br Nr Hadley	2450	4040	5.3	--	02/10 09:45
01327750	Hudson River At Fort Edward	4460	7620	22.5	--	02/10 09:00
01329500	Batten Kill At Battenville	440	--	3.8	--	02/10 09:00
01334500	Hoosic R Nr Eagle Bridge	550	1290	4.4	--	02/10 08:45

Stage -- updated Fri Mar 5 14:30 1999 -- download presentation-quality graph

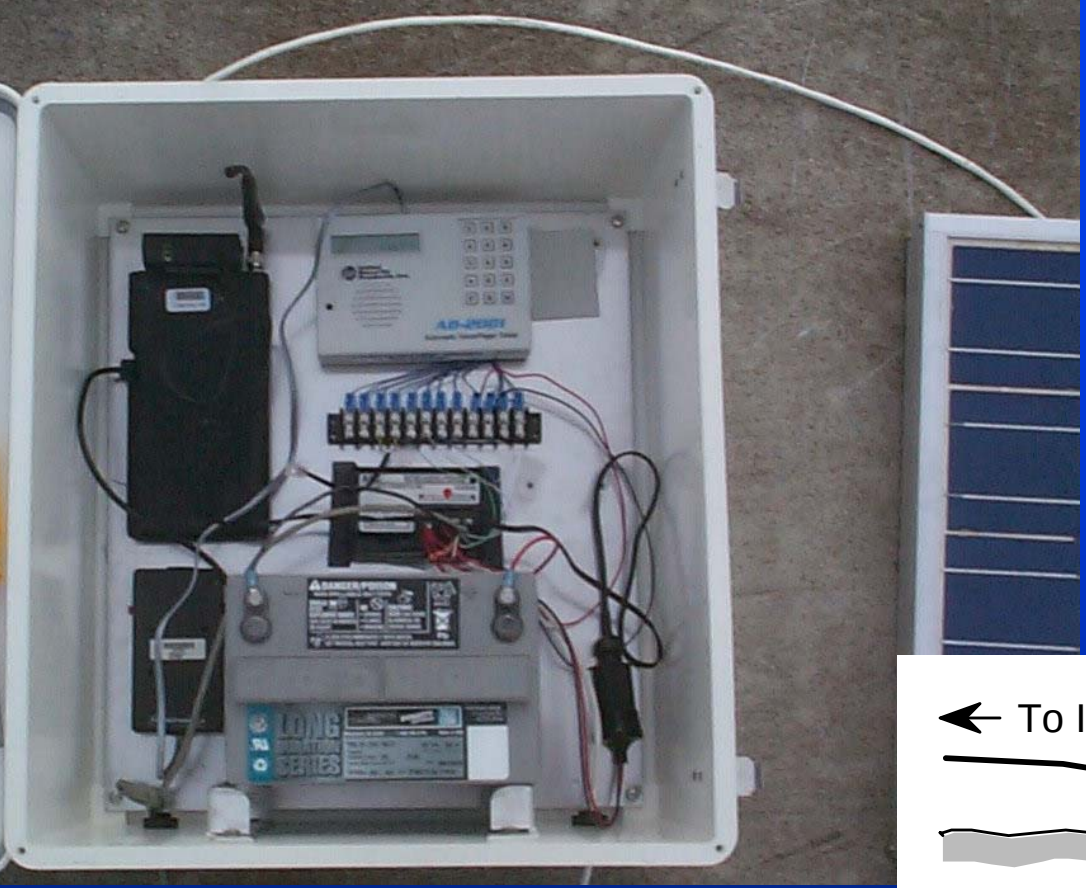


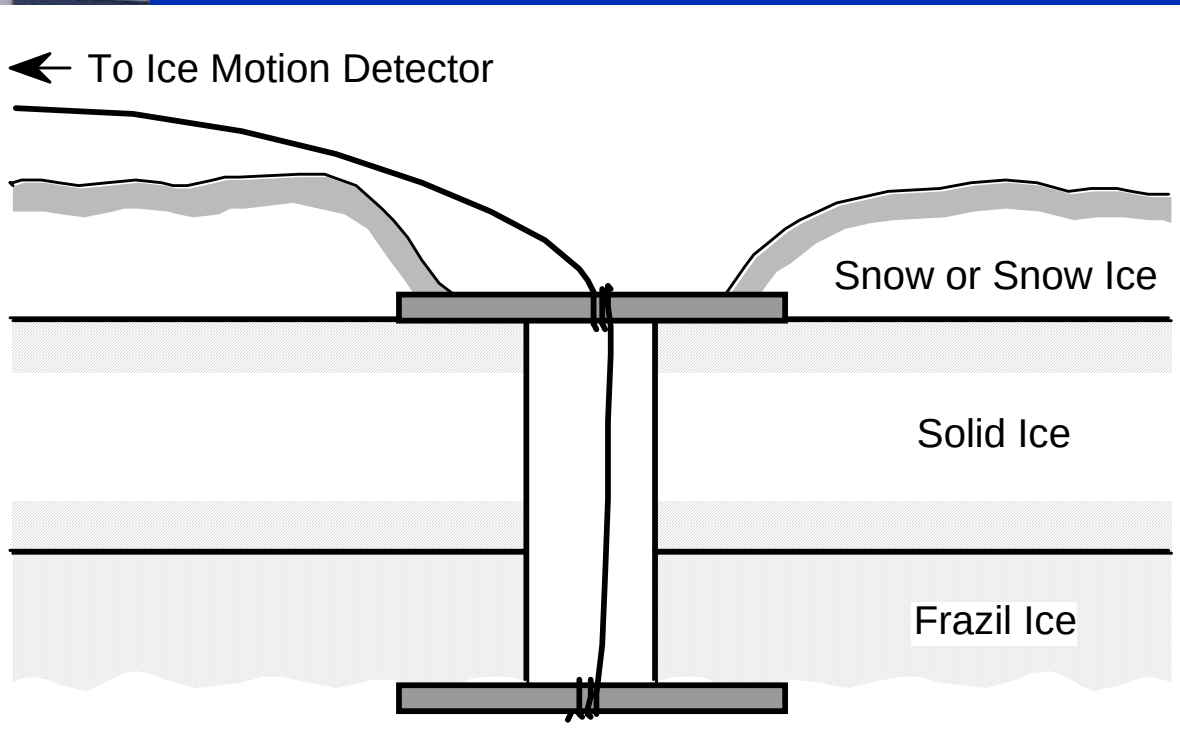
- Data used in graph
- Historical daily mean or peakflow data for this station
- Return to Current Streamflow Conditions table

Station Description

01031500 PISCATAQUIS RIVER NEAR DOVER-FOXCROFT, MAINE

Aerial photographs




To Ice Motion Detector
Snow or Snow Ice
Solid Ice
Frazil Ice


LONG
DURATION
SERIES

Ice Weakening

- Mechanical: Immediate strength reduction
  - Ice cutting
    - 4WD trencher
    - amphibious ice saw
  - Ice breaking
    - amphibious excavator
    - vessels
- Thermal: Accelerate natural ice deterioration
  - Hole drilling
  - Dusting

Ice Cutting

- Beaurivage River, Quebec
  - 4WD trencher
  - diagonal slot pattern, center 2/3
  - ice moves through cut area

Ice Breaking

- Icebreakers/towboats
  - – can clear channels in jams
- hovercraft
  - – effective for sheet ice

Hole Drilling

- Oconto River, WI
  - 10 ft grid, central 2/3 of channel
  - holes expand to weaken sheet
  - ice moves into Lake Michigan

Aerial Dusting

- Yukon River, AK
  - sand increases solar absorption
  - 25 years, high productivity
  - difficult to assess effectiveness

Emergency Measures

- Jam in place
- Cost & effectiveness depend on timing
  - try to minimize damages
  - time is critical
- Excavation
- Blasting
- Flood Fighting
- Do nothing
- Lead time = effectiveness

Excavation

- Most efficient when stage rising
- Pre-positioned equipment helpful
  - excavator, clam-shell, bulldozer
  - clear channel D/S of toe
  - dislodge key pieces at toe
- Expensive to excavate ice pieces after stage falls
- Can be combined with blasting (excavate where safe, blast upstream end of jam)

Excavation Examples

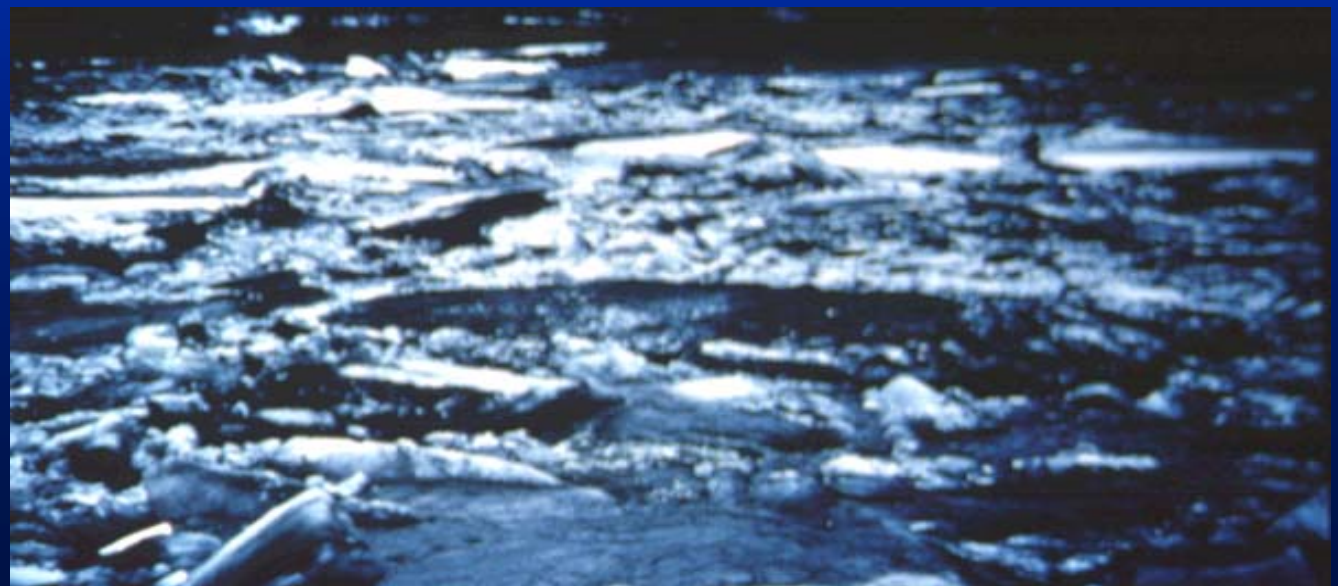
- Gorham, NH
- Morrisonville, NY

Blasting

- Requires open water downstream
- Work from downstream to upstream
- Charges should be placed just under ice
- Pre-planning needed (liability issues, rapid response)
- Not suitable for urban area

Do Nothing

- Thin, weak ice
- Little remaining ice supply
- Continued mild temperatures
- Late season jam (check records)
- Other constraints



Permanent Measures

- Structural solutions
  - Ice control structures (ICS's)
  - Diversion channels
  - Flow control
  - Thermal discharge
  - Levees, floodwalls
  - Flood proofing
  - Land management
- 2-5 year lead time
- Expect high benefits and reliability
- Generally costly although some low-cost solutions are under development

Structural

	Jam Type Technique	Type of Mitigation
Dikes, levees, floodwalls	F,B	P
Dams and weirs	F,B	P
Ice booms	F,B	P,A
Retention structures	B	P
Channel modifications	F,B	P
Ice storage zones	B	P,A

Nonstructural

Forecasting	F,B	A,P
Monitoring and detection	F,B	E,A,P
Floodproofing	F,B	P
Sandbagging	F,B	A,E
Evacuation	F,B	A,E
Levee closing	F,B	A,E
Thermal control	F,B	E,A,P
Land management	F,B	P
Ice cutting	B	A
Operational procedures	F,B	A,P
Dusting	F,B	E,A
Ice breaking	F,B	E,A
Mechanical removal	F,B	E,A
Blasting	F,B	E,A

Key: B=Breakup jam, F= Freezeup jam, P= Permanent measure
A= Advance measure, E= Emergency measure